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The edible snails of Côte d'Ivoire: effects of photoperiod on the growth and the reproduction performances of *Achatina achatina* (Linné, 1720) in indoor rearing

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Abstract

Achatina achatina (Linné) snails with 42 g average body weight and 68 mm average shell length were submitted five photoperiods during two experiments (growth and reproduction) of three months each, in order to determine their effects on the growth and the reproduction performances. Long photoperiods dominated by light stimulated growth and reproduction parameters while these were inhibited by short photoperiods of light. The photoperiod of 24h of light gave the better growth performance, lower food intake and percentage of cumulative mortality. The photoperiod of 18h of light and 6h of dark gave the better reproduction performance.

Riassunto

Esemplari di *Achatina achatina* (Linné) di 42 g di peso medio e di 68 mm di lunghezza media sono stati sottoposti a cinque fotoperiodismi diversi nel corso di due esperimenti (crescita e riproduzione) della durata di tre mesi ciascuno, con lo scopo di determinare i loro effetti sulla crescita e sulla capacità di riproduzione. I fotoperidismi lunghi favoriscono la crescita e la riproduzione, mentre quelli brevi le inibiscono. Il fotoperiodismo di 24 ore di luce su 0 ore di oscurità dà il maggior rendimento di crescita, un più basso fabbisogno alimentare ed un più basso tasso complessivo di mortalità. Il fotoperiodismo di 18 ore di luce su 6 ore di oscurità dà i migliori rendimenti riproduttivi.

Key words

Achatina achatina (Linné), growth, reproduction, photoperiod.

Introduction

The land snail *Achatina achatina* (Linné) is one of the most common and conspicuous mollusc in the dense forests of Côte d'Ivoire. These molluscs are very rich in proteins, minerals and singularly in iron (Aboua, 1990), and constitute an alternative source of animal proteins and iron for rural populations. *Achatina achatina* (Linné) is in fact very exploited in Côte d'Ivoire and consumed in many different ways (Aboua & Boka, 1995). Its breeding is therefore necessary to compensate seasonal deficit and to preserve the species from many plagues such as the destruction of the forests, the abusive use of pesticids and over collecting. However, many attempts of breeding gave very unsatisfactory results because of the use of wrong plants in the diet and the lack of control on certain ecological factors. The snails breeding requires in fact a careful control of many ecological parameters and of biotic and abiotic factors. Among the abiotic factors, the photoperiod plays an essential role in the life of snails. Le Guhennec (1985) showed that the red monochromatic light stimulates the reproductive capacities of the snail *Helix aspersa* (Müller) by favouring the laying and the reproduction. Aupinel & Daguzan (1987) studied the role of the photoperiod on the metabolic activity of young snails *Helix aspersa* (Müller) while Hodasi (1982) studied the effect of various light regimes on the life of the snail *Achatina achatina* (Linné) nourished exclusively with green fodder. However, the effect of the photoperiod on the growth and the reproduction of the snail *Achatina achatina* (Linné) nourished with floured concentrated diet in indoor breeding was not studied yet. In the present contribution we studied the effect of various photoperiods on the growth and reproductive performances of *Achatina achatina* (Linné) in indoor breeding in order enhance the knowledge of the biology of this species and help the rearing.

Materials and methods

Animals

Seven hundred and fifty snails of the species *Achatina achatina* (Linné) of 41.75 ± 7.49 g of average live weight and 68.50 ± 5.64 mm of average shell length were used. Their age, estimated from curves of linear growth (Hodasi, 1979; Otchoumou *et al.*, 1989-1990; 2003a; 2003b; Zongo *et al.*, 1990) was approximately fourteen months. They were collected in the forests of south-west Côte d'Ivoire from an area of approximately 2 hectares and were acclimatized in the laboratory for two weeks prior to experimentation under the following ambient conditions: temperature and average relative humidity of 26 ± 1.3°C and 82.9 ± 1.2%, respectively, with a 12L:12D photoperiod. They were nourished with fresh leaves of pawpaw tree (Caricaceae: *Carica papaya*) during this period.

Diets

After two weeks of laboratory habituation, the snails were nourished with:

- a floured diet of 12.02% calcium content during growth experiment.
- a floured diet of 6.82% calcium content during reproduction experiment. Otchoumou *et al.*, (2004a; 2004b) studying effects of some vegetables, concentrated diets and dietary calcium on growth and reproduction in *Achatina achatina* showed that the best growth performances are obtained, in this species, using a diet with 12.02% calcium content, while the best reproductive performances are obtained with a diet with 6.82% calcium content.

Light regimes

Five photoperiods were tested: 24L:0D; 18L:6D; 12L:12D; 6L:18D and 0L:24D. The intensity of the illumination was 60 lux. In practice, photoperiods were programmed in the following way:

- 24L: 0D, breeding containers are lightened during 24 hours and do not receive darkness throughout all experiment.
- 18L: 6D, containers are lightened from 6 o'clock in the morning (universal time) to 12 o'clock in the night (midnight) and receive darkness from 12 o'clock in the night to 6 o'clock in the morning.
- 12L: 12D, containers are lightened from 6 o'clock in the morning (universal time) to 18 o'clock and receive darkness from 18 o'clock to 6 o'clock in the morning.
- 6L:18D, containers are lightened from 6 o'clock in the morning to 12 o'clock (universal time) and receive darkness from 12 o'clock (midday) to 6 o'clock in the morning.
- 0L:24D, Breeding containers receive darkness throughout all experiment.

Change from light to darkness and conversely is done gradually and the transitional period lasts 5 minutes. Three repetitions per each photoperiod were carried out.

Breeding and collection of the parameters of growth and reproduction

The snails were reared in wooden containers with the density of 100 snails/m^2 (50 snails per container). The 15 breeding container were parallelepipeds ($L \times l \times H = 1 \times 0.5 \times 0.15$ m). The interior of the container was covered with a wet foam "standard mattress" 2 cm thick. The foam was in its turn covered by a cotton fabric preserving container's moisture. The higher part of the lid of each container was covered with a perforated black plastic film creating total darkness inside. A daily programmer "VOLTMAN®" of 220V connected to the sector fed an array of bulbs to an intensity of 1A. The non-heating bulbs were inserted under the black plastic film of the lid and emitted a white light into the interior of the containers. The programmers were regulated to begin each day at six o'clock in the morning. The containers were set randomly on shelves of three stages installed against the interior walls of a building. Growth experiment lasted three months (June-August 2002) and snails were nourished with growth diet. Reproduction experiment started two weeks after the end of the growth experiment. During these two weeks, snails were nourished with reproduction diet in order to habituate them to it. Each fifteen days, twenty five snails were taken randomly in each container, weighed using a "Sartorius" balance (precision of 0.01 g) and snail shell lengths measured with an electronic caliper (precision of 0.01 mm). Mortalities were noted. Snails (pilots) with the same live weights and shell lengths subjected to the same conditions of photoperiod and food intake permitted to replace dead snails in order to preserve the starting densities.

Components (g)													
	Corn	Cotton cattle-cake	Soya grains	Fish meal (scale)	Bran soft wheat	Calcium phosphate	Vitamins	Calcium carbonate	Salt	Salt-phoscal (snail)	Trace elements	Agar-agar	Total
R_3	10.00	16.00	16.00	–	15.00	4.00	0.50	28.70	0.40	–	0.10	9.30	100
R_T	13.00	10.00	–	12.00	50.00	–	–	–		15.00	–	–	100

Characteristics (% in dry matter)									
	Crude energy	Nitrate matter	Total calcium	Fats	Starch	Free sugars	Crude cellulose	Ash	Crude proteins
R_3	2785	17.48	12.02	4.71	12.56	3.10	4.76	33.43	–
R_T	2040	–	6.82	4.12	18.87	3.41	7.23	23.47	23.36

Components chemical analysis (% of dry matter)					
	Dry matter	Proteins	Total Lipids	Minerals	Energy (cal/g)
R_3	91.10	20.27	2.50	36.07	2.851
R_T	89.35	24.51	1.72	20.93	3.617

Tab. 1. Meal diet components, characteristics and chemical analysis.

Tab. 1. Componenti della dieta alimentare, caratteristiche ed analisi chimiche.

Food was given to the snails every four days. At the end of that period, the refusal of the food was weighted after having been dried at 80°C for 24 hours, and the containers cleaned. For each diet a pilot of 100 g, dried at 80°C allowed an estimate of the dry weight food intake. Growth measurements were carried out during growth experiment. Concerning reproduction experiment, the eggs laid were collected each day and weighted. The eggs were counted and three of them, randomly selected in each laying, were measured using the electronic caliper (major and minor diameter). Each laying was incubated under the following environmental conditions: temperature of 26 ± 1.3°C and average relative humidity of 82.9 ± 1.2%, with a 12L:12D photoperiod on a substrate of coconut envelopes (Palmaceae: *Cocos nucifera*) until hatching. Juveniles were then counted.
Snails were followed during three months (September, October and November) for reproduction experiment. Growth and reproduction experiments were carried out under the same climatic conditions of temperature and humidity.

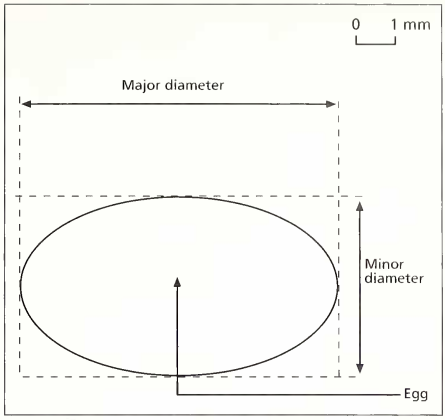

Fig. 1. Criteria of an Achatinidae egg measurement.

Fig. 1. Parametri per la misura delle uova di Achatinidae.

Statistical analyses

Statistical analyse of the data were carried out with the SAS® program (1987). Growth data and reproduction data were analysed separately. Averages of the parameters of growth and reproduction were compared by variance analysis with ANOVA test (Dagnelie, 1975) at 105 days for growth parameters and at 225 days for reproduction parameters (threshold of confidence 5%).
For live weight, shell length, number of eggs per laying and number of juveniles per laying data, we used the following model:

$$Y_{ijk} = \mu + R_i + B_{ij} + E_{ijk}$$

where Y_{ijk} is the measured variable, μ the general average, R_i the fixed effect of the photoperiod, B_{ij} the effect of the repetition and E_{ijk} the residual.
The number of levels within each factor was 294 for live weight and shell length than 36 for number of eggs per laying and number of juveniles per laying.
For food intake, cumulated mortality, total number of eggs per laying, average weight of eggs, average large diameter and average small diameter of eggs data, the model utilised was:

$$Y_{ij} = \mu + R_i + E_{ij}$$

where Y_{ij} is the measured variable, μ the general average, R_i the fixed effect of the photoperiod and E_{ij} the residual.
The number of levels within each factor was 15 for food intake and cumulated mortality, 36 for total number of eggs per laying than 108 for average weight of eggs, average large diameter and average small diameter of eggs.
A Pearson product moment correlation between the various parameters of growth and between the various parameters of reproduction was calculated.

Results

Growth

The mean values of live weights and shell lengths obtained from all the observations were 94.16 ± 21.26 g and 80.59 ± 6.05mm respectively (**Tab. 2**). The mean rate of food intake and cumulative mortality were 65.53 ± 30.17×10^{-4} g/day/g of live weight and 21.60 ± 10%, respectively.
The curves of the live weight showed, according to time and the photoperiods (**Fig. 2**), a weak growth from 0 to 15 days, a steep sloping increase in growth from 15 to 45 days followed by a plate from 45 to 90 days, then a strong almost exponential growth from 90 to 105 days for the light regimes 24L:0D, 0L:24D and 18L:6D; in 12L:12D and 6L:18D, this increase is fare less marked.

	Number of observation	Means	SD	Min	Max	Skewness	Kurtosis
Live weight (g)	294	94.16	21.26	40.68	189.00	0.45	0.94
Shell length (mm)	294	80.59	6.05	62.00	97.00	-0.24	0.09
Food intake ($.10^{-4}$ g/day/g of live weight)	15	65.53	30.17	29.02	138.07	0.34	0.30
Mortality (%)	15	21.60	10.00	4.00	48.00	0.02	0.81

Tab. 2. Elementary statistics of growth characters.

Tab. 2. Statistiche dei caratteri di crescita.

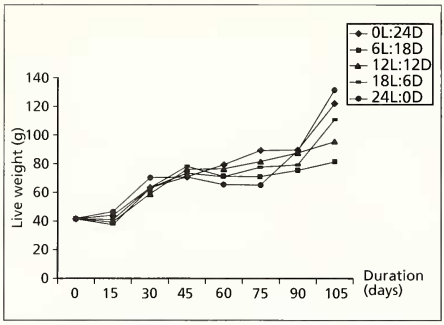

Fig. 2. Effects of photoperiod on live weight of *Achatina achatina* (Linné).

Fig. 2. Effetti del fotoperiodismo sul peso fresco di *Achatina achatina* (Linné).

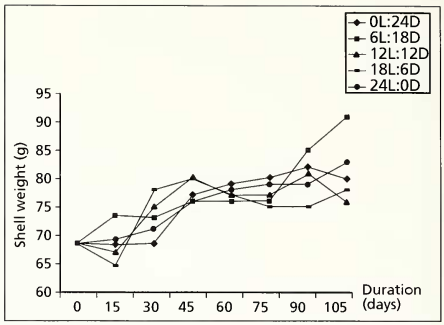

Fig. 3. Effects of photoperiod on shell lenght of *Achatina achatina* (Linné).

Fig. 3. Effetti del fotoperiodismo sulla lunghezza della conchiglia di *Achatina achatina* (Linné).

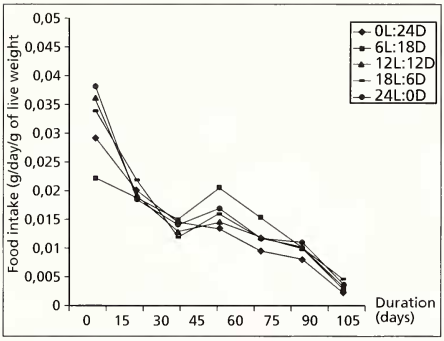

Fig. 4. Effects of photoperiod on the food intake of *Achatina achatina* (Linné).

Fig. 4. Effetti del fotoperiodismo sull'alimentazione di *Achatina achatina* (Linné).

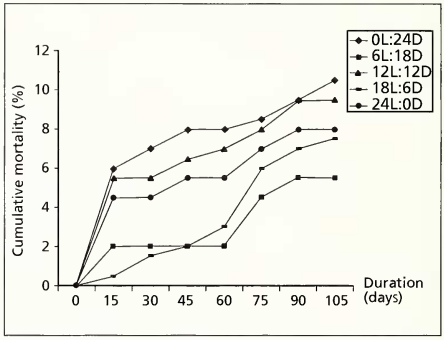

Fig. 5. Effects of photoperiod on cumulative mortality of *Achatina achatina* (Linné).

Fig. 5. Effetti del fotoperiodismo sulla mortalità totale di *Achatina achatina* (Linné).

The curves of shell growth (**Fig. 3**) presented as a whole a strong growth from 15 to 45 days, a weak growth from 45 to 75 days for all the light regimes excluded the photoperiod 6L:18D, whose curve decreased from 45 to 75 days. Thereafter, the curves of photoperiods 24L:0D, 0L:24D and 6L:18D presented a strong growth from 75 to 105 days while those of 12L:12D and 18L:6D grew from 75 to 90 days then decreased from 90 to 105 days.

Food intake (**Fig. 4**) strongly decreased from15 to 45 days, grew from 45 to 60 days then decreased from 60 to 105 days. As for the death rate cumulated mortality according to time and photoperiods (**Fig. 5**), it presented a strong slope at the beginning then grew slightly up to 105 days for all the light regimes. It is noted that photoperiod 24L:0D gave the best performances of growth for a low food intake, and a cumulated mortality of 21.33%.

The statistical analyses (**Tab. 3**) showed a significant difference ($P < 0.05$) between photoperiods 24L:0D and 0L:24D, then between photoperiods 18L:6D, 12L:12D,

	Light regimes				
	24L:0D	**18L:6D**	**12L:12D**	**6L:18D**	**0L:24D**
Live weight (g)	131.26^{a}	110.53^{c}	95.75^{c}	80.92^{c}	121.96^{b}
Shell length (mm)	91.00^{a}	80.00^{a}	76.00^{a}	78.00^{a}	83.00^{a}
Food intake (.10^{-4} g/day/g of live weight)	51.76^{b}	118.2^{a}	58.23^{b}	39.35^{b}	60.13^{b}
Mortality (%)	21.33^{a}	16.00^{a}	16.00^{a}	30.66^{a}	24.00^{a}
The same line mean values indexed by the same letter have no significant differences ($P < 0.05$)					

Tab. 3. Effect of photoperiod on growth characters.

Tab. 3. Effetti del fotoperiodismo sui caratteri di crescita.

	Live weight	Shell length	Food intake	Mortality
Live weight	1			
Shell length	0.84**	1		
Food intake	-0.94	-0.69	1	
Mortality	0.54	0.33*	-0.39	1

**= P < 0.001
*= P < 0.01

Tab. 4. Correlation between growth characters.

Tab. 4. Rapporti tra i caratteri di crescita.

6L:18D and photoperiods 24L:0D and 0L:24D for the live weights.

On the other hand, there was not significant difference (P > 0.05) between the shell lengths and the cumulated mortality whatever the photoperiod. However for food intake, there was a significant difference (P < 0.05) between photoperiod 18L:6D and photoperiods 24L:0D, 12L:12D, 6L:18D and 0L:24D.

The analysis of the correlations between the various parameters of growth (**Tab. 4**) shows a very strong correlation (P < 0.001) between the live weights and the shell lengths(r = 0.84). However, live weights and shell lengths were not correlated with food ingestions (r = – 0.94 and – 0.69 respectively).

Reproduction

The elementary statistics for the average values of number of laying, weight, major and minor diameter of eggs, number of eggs per laying, average duration of incubation and number of juveniles per laying is given in **Tab. 5**. The regimes of 6L:18D and 0L:24D did not give any hatching at the end of one month.

The statistical analyses (**Tab. 6**) show that there was a significant difference (P < 0.05) for the total number of laying and the average number of eggs per laying between photoperiod 24L:0D and photoperiods 18L:6D, 12L:12D, then photoperiods 6L:18D, 0L:24D. On the other hand there was no significant difference (P < 0.05) between the photoperiods tested for the average weight, the large and the small diameter of eggs. The duration of incubation of eggs for the regime of 12L:12D was statistically different from the one for the regimes of 24L:0D and 18L:6D.

The number of juveniles per laying and the percentage of hatching of photoperiod 24L:0D were statistically different from those of photoperiods 18L:6D and 12L:12D.

The analysis of the correlations between the various parameters of reproduction showed a correlation between the total number of laying and the number of eggs per laying, the duration of incubation and the number of juveniles per laying (**Tab. 7**). The average

	Number of observation	Means	SD	Min	Max	Skewness	Kurtosis
Total number of laying	36	15.80	11.39	1.00	36.00	0.1	0.25
Average weight of egg (g)	108	0.16	0.02	0.14	0.20	0.27	0.48
Major diameter (mm)	108	6.10	0.22	6.00	6.50	0.23	0.5
Minor diameter (mm)	108	5.10	0.44	4.50	6.00	0.29	0.38
Number of eggs/laying	36	36.70	17.49	11.00	56.50	– 0.57	0.17
Duration of incubation (days)	36	15.66	10.95	12	20	0.60	-3.33
Number of juveniles/hatching	36	29.20	4.38	6.00	48.00	– 0.18	0.79
Percentage of hatching	36	69.37	10.24	0.00	82.55	0.21	0.91

Tab. 5. Elementary statistics of reproduction characters.

Tab. 5. Statistiche dei caratteri riproduttivi.

	Light regimes				
	24L:0D	18L:6D	12L:12D	6L:18D	0L:24D
Total number of laying	11.00^{b}	30.00^{a}	36.00^{a}	1.00^{c}	1.00^{c}
Average weight of egg	0.16^{a}	0.16^{a}	0.14^{a}	0.20^{a}	0.15^{a}
Major diameter (mm)	6.00^{a}	6.5^{a}	6.00^{a}	6.00^{a}	6.00^{a}
Minor diameter (mm)	5.00^{a}	5.00^{a}	4.50^{a}	6.00^{a}	5.00^{a}
Number of eggs/laying	11.00^{c}	56.00^{a}	49.00^{a}	34.00^{b}	33.00^{b}
Duration of incubation	15.00^{b}	12.00^{b}	20.00^{a}	–	–
Number of juveniles/hatching	5.48^{b}	46.23^{a}	37.12^{a}	–	–
Percentage of hatching	49.8^{b}	82.55^{a}	75.75^{a}	–	–
The same line mean values, indexed by the same letter have no significant difference (P < 0.05)					

Tab. 6. Effect of photoperiod on reproduction characters.

Tab. 6. Effetti del fotoperiodismo su i caratteri riproduttivi.

	Total Number of laying	Average Weight of egg	Big diameter	Small diameter	Number of eggs/ laying	Duration of incubation	Number of spats/ hatching	Percentage of hatching
Total number of laying	1							
Average weight of egg	– 0.46	1						
Big diameter	0.51*	0.04	1					
Small diameter	– 0.61	0.97**	– 0.10	1				
Number of eggs/laying	0.81**	– 0.13	0.63*	– 0.23	1			
Duration of incubation	0.99**	– 0.42	0.61*	– 0.58	0.83**	1		
Number of spats/hatching	0.76**	– 0.57	– 0.15	– 0.63	0.46*	0.68*	1	
Percentage of hatching	0.74**	– 0.56	– 0.18	– 0.62	0.44*	0.66*	0.99**	1

** = P < 0.001
* = P < 0.01

Tab. 7. Correlation between reproduction characters.

Tab. 7. Rapporti tra i caratteri riproduttivi.

weight of an egg and the small diameter were strongly correlated as is between the number of eggs per laying and the duration of incubation (P < 0.001). Weak to strong correlations exist between the average weight and the major diameter of eggs, and between the number of eggs per laying and the duration of incubation (**Tab. 7**).

Discussion

The long term effects of the photoperiod on the growth and the reproduction of Helicidae has been studied. Aupinel & Daguzan (1987) had defined a threshold photoperiodic of activity for *Helix aspersa* (Müller). This threshold was around 15 hours of photophase (lasted of the illumination) and a photophase lower than 15 hours induced the inactivity independently of the temperature and hygroscopy. A photophase higher than 15 hours stimulated the growth and the reproduction.
Our results showed that both weight and shell growths had better performances for a photophase ranging between 18 hours and 24 hours. However, the 24 hours photophase gave the best growth performances, while the 18 hours photophase recorded the weakest cumulated mortality. Long photophases would thus stimulate the physiological activity of *Achatina achatina* and particularly its growth.
Hodasi (1982) showed that *Achatina achatina* reared in continuous light presented a growth higher than those of individuals of the same species subjected to the total darkness. Egonmwann (1991) showed that *Limicolaria flammea* (Müller) subjected to 16 hours of light and 8 hours of darkness had a growth higher than that of individuals of the same species subjected to 12 hours of light and 12 hours of darkness. Otchoumou (1997) studying the effect of two photoperiods (12L:12D and 0L:24D) on the growth of *Achatina achatina*, *Achatina fulica* and *Archachatina ventricosa* showed that 12L:12D induced better growths compared to 0L:24D.
The strong correlations between live weight and shell

Parameters	Alpha	Confidence	df	MSE	Critical value of T	F value	Pr > F	Minimum signif. dif.
Live weight	0.05	0.95	279	446.42	2.82	1.28	0.10	1.24
Shell length	0.05	0.95	279	35.60	2.82	1.93	0.04	0.35
Food intake	0.05	0.95	10	0.00000154	3.58	18.07	0.0001	0.0036
Mortality	0.05	0.95	10	94.93	3.58	1.19	0.37	28.492
Total number of laying	0.05	0.95	10	20.8	3.58	0.94	0.47	13.33
Number of eggs/laying	0.05	0.95	10	0.68	3.58	2.16	0.14	2.41
Average weight of egg(g)	0.05	0.95	10	0.12	3.58	0.39	0.81	1.03
Major diameter(mm)	0.05	0.95	10	2	3.58	0.22	0.92	4.13
Minor diameter(mm)	0.05	0.95	10	0.25	3.58	0.23	0.91	1.46
Duration of incubation (days)	0.05	0.95	10	107.8	3.58	0.88	0.51	30.36
Number of juveniles/hatching	0.05	0.95	10	0.26	3.58	0.53	0.71	1.51
Percentage of hatching	0.05	0.95	10	0.30	3.58	0.54	0.34	1.40

Tab. 8. Results of ANOVA's.

Tab. 8. Risultati dell'analisi ANOVA.

length on the one hand, and between shell length and food intake on the other hand, would be explained by the fact that the nutrients consumed in abundance would be used for both weight and shell growth and that weight and shell growth would be closely dependent, also due to the allometric relationships phenomenon (Wilbur & Owen, 1964; Gould, 1966).

Everything suggests us that photoperiods did not affect allometric relationships in *Achatina achatina*. The results obtained for the total number of laying, dimensions of eggs, the duration of incubation and the percentage of hatching were similar to those of Otchoumou (2003a).

The observation of the parameters of reproduction showed that the photoperiod influenced the reproduction of *Achatina achatina*. Thus the parameters of reproduction were better for a photophase ranging between 18 and 24 hours. In this photoperiodic range, the 18 hours photophase gave the greatest number of depositions, the best average number of eggs per laying, the shortest duration of incubation and the best number of spats per laying.

Our results suggest us that the longer was the photophases, the better are the reproductive performances of *Achatina achatina*, while a 6 hours photophase would inhibit them. Therefore *Achatina achatina* would be thus a species whose physiological activities would be stimulated by the long photophases.

The strong correlations between the total number of laying and the number of eggs per laying on one hand and the duration of incubation and the number of juveniles per laying on the other hand, would mean that the more the total number of laying increased, the shortest was the duration of incubation and the highest was the percentage of hatching. The negative correlations between the live weights then the shell lengths and the average weights then dimensions of eggs would mean that for *Achatina achatina*, the quality of eggs would not depend on the morphological characteristics of the animals. However, the quality of eggs would be also related to a good food ingestion.

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